Thermoelectric Sample Conditioner System (TESC-2983)

FULLY AUTOMATED ASTM D2983 CONDITIONING AND TESTING ON THE CANNON® TESC SYSTEM WHITE PAPER

A critical performance parameter for transmission, gear, and hydraulic lubricants is low temperature viscosity. ASTM D29831 provides a procedure and specifications for measuring the low temperature viscosity of lubricants (Brookfield Viscosity2). The first edition of this method specified a refrigerated, forced-air cabinet for low temperature conditioning and did not include a sample preheat process. The current preheat process was added to the method in the early 1980's.

Cannon Instrument Company has developed a fully automated Thermoelectric Sample Conditioner (TESC) System for D2983. With the incorporation of a Brookfield DV2T digital viscometer and thermoelectrically controlled sample chamber, the TESC System is the first instrument to automate the entire conditioning and testing process. This includes preheating, room temperature stabilization, cooling of the sample to test temperature3, and testing final viscosity of the conditioned sample. Automation lessens the hands-on time needed to prepare and run a D2983 viscosity test, reduces variability, and improves test precision.

Procedure

The CANNON TESC System uses ASTM D2983method Procedure D. To reduce test variability, the TESC System automates or removes many of the steps required to transfer the sample between conditioning and testing processes. Automation occurs through use of a thermoelectrically controlled sample chamber that manages the sample, without operator intervention, throughout the conditioning and testing processes.

Using a calibrated TESC System, an operator runs a D2983 test as follows:

1. Auto-zero the Brookfield DV2T viscometer.
2. Measure 20 mL of sample into a 25 mm × 150 mm, rimless test tube.
3. Carefully place the test tube with the sample into the TESC sample chamber.
4. Attach a #4B2 spindle to the DV2T and lower the viscometer into the run position.
5. Launch both the temperature control program and the viscometer program.

Once the temperature control program starts, the TESC System heats the sample to the preheat temperature and maintains it at that temperature for the required time. The TESC System then cools the sample to room temperature at the same rate used to raise it to the preheat temperature, and then further cools the sample to the desired test temperature according to the equation in D2983 Annex A1. This controlled heating and cooling is critical to reducing variability.

[1] ASTM D2983 Standard Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer (http://www.astm.org/Standards/D2983.htm)

[2] Testing of the low temperature viscosity of lubricants is commonly referred to as a “Brookfield Viscosity” because the method was developed using Brookfield rotational viscometers.

[3] The cooling profile is described in Annex 1 of ASTM D2983.

Throughout the thermal conditioning process, the DV2T program records the temperature of the sample chamber while waiting to measure the viscosity. When thermal conditioning of the sample completes, the DV2T automatically measures the sample viscosity by stepping through the typical range of spindle speeds for the sample type or expected viscosity. This eliminates the need to run multiple tubes of a sample. Once the viscosity measurements finish, the TESC System returns the sample to room temperature, nominally 25 °C. Afterwards, the operator can review the data and enhance the digital record with notes and additional information. The TESC System comes with a set of thermal conditioning programs for all of the common specification test temperatures as well as certain OEM measurement and report requirements.

Table 1: TESC-5133 Thermal Conditioning Programs

Fluid	Preheat Temperature	Test Temperature
Low viscosity (ATF, hydraulic fluid)	50 °C	−10 °C −20 °C −30 °C −40 °C
High viscosity (gear oil)	90 °C	−12 °C −26 °C −40 °C

A spreadsheet is provided to enable users to create thermal conditioning programs for test temperatures other than those provided.

Data

The data presented in Table 2 demonstrate extensive testing of ASTM Inter-Laboratory Crosscheck Program (ILCP) samples with the TESC system4. Data for both Automatic Transmission Fluid (ATF) and Gear Oil samples were obtained using two TESC preproduction systems incorporating a DV2T viscometer. Results were calculated as follows:

Repeatability: ATF repeatability was calculated using 32 repeat determinations of ILCP samples at the same spindle speed. Gear oil repeatability data was calculated based on four repeat determinations of ILCP samples at the same spindle speed.

The difference between two viscosity determinations for each ILCP sample, at a single speed on a single TESC system was divided by the average of the two to establish a “Repeatability %” for each sample/spindle speed. The “Repeatability %” for all samples/spindle speeds was then averaged and reported as “Average Comparison %” in Table 2. The standard deviation of the “Repeatability %” for all ILCP samples/spindle speeds was calculated and reported in Table 2 as “Standard Deviation, %” and represents an estimate of the variation in the “Repeatability %” for the TESC System.

Reproducibility: ATF reproducibility data represent 84 viscosity determinations made at the end of 42 tests on 13 ILCP samples. Gear oil reproducibility data represent 52 viscosity determinations made at the end of 18 tests on eight samples.

The difference between the single spindle speed TESC System viscosity determination of an ILCP sample and the sample’s accepted value at that speed (as established in the ILCP report) was divided by the average of the two to establish a “Reproducibility %” for each sample/spindle speed. The “Reproducibility %” for all samples/spindle speeds was then averaged and reported as the “Average Comparison %” in Table 2. The standard deviation of the

“Reproducibility %” for all ILCP samples/spindle speeds was calculated and reported in Table 2 as “Standard Deviation, %” and represents an estimate of the variation in the “Reproducibility %” for the TESC System.

Table 2: ASTM ATF & GO ILCP Sample Data Summary

Product	Temperature	Precision	Average Comparison, %	Standard Deviation, %
ATF	–40 °C	Repeatability	0.80	1.68
ATF	–40 °C	Reproducibility	2.79	3.55
Gear Oil	–26 °C	Repeatability	1.12	0.40
Gear Oil	–26 °C	Reproducibility	0.62	6.31

[4] For complete sample data sets, see Table 4 and Table 5.

Published precision for D2983 viscosity is shown in Table 3 compared to estimated TESC System precision[a]. The data suggests exceptional repeatability and reproducibility as compared to current D2983-09 and 2014 proposed values for gear oils and ATF[5].

Table 3: ASTM D2983 Precision

ASTM D2983	2009 Current Standard	2014 Proposed Revision	TESC System Estimates[a]
Repeatability	3.4 %	13.78 %	2.7 %
Reproducibility	20.6 %	18.28 %	8.6 %

[a] Reproducibility and repeatability are estimated based data collected in two laboratories, on two TESC systems from eight samples (six ATF and two gear oil). While this does not meet ASTM precision statement calculation requirements, results are consistent with variance seen in the ILCP sample testing data for the TESC System.

Discussion and Conclusion

As demonstrated in the data comparison between the TESC System and the method's published precision, the TESC System is capable of meeting reproducibility and repeatability requirements for ASTM D2983 for both gear oils and ATF. It is the first ASTM D2983 sample conditioning system that automates not only the low temperature portion of the thermal conditioning process, but also the preheat and room temperature stabilization steps. Because all conditioning steps are carried out with the sample in place in the sample chamber, the TESC System minimizes or eliminates many data quality issues associated with temperature fluctuation and sample disruption during D2983 conditioning and viscosity measurement; decreasing variability.

Like other conditioning options for D2983 Procedure D, the sample is cooled during low temperature conditioning according to the equation in D2983 Annex A1. However, the TESC System also incorporates programmed preheat and room temperature stabilization profiles to ensure samples experience exactly the same conditions throughout the entire conditioning process. Furthermore, because samples are not physically transported between each conditioning step and then to the viscometer, temperature fluctuation resulting from transport is effectively eliminated. This ensures more consistent thermal conditioning and a repeatable viscosity measurement temperature. Incorporation of a compact sample chamber, only slightly larger than the sample stator, creates a tightly controlled conditioning environment and minimizes concerns about variation in coolant circulation in the TESC System. In the run position, the DV2T viscometer completely covers the sample chamber and isolates it from ambient conditions throughout sample conditioning and testing to ensure consistent temperature control.

A reference standard run during instrument set up confirms appropriate instrument programming, calibration, and temperature control. Sample chamber temperatures are automatically measured by an integrated RTD temperature sensor throughout the conditioning and testing process. The thermal conditioning history is included in the data file along with measured viscosity and can be obtained by the user after test completion.

In addition to advanced thermal control, elimination of the need for sample transport allows the TESC System to improve test precision through reduced sample disruption. The importance of minimizing sample disruption is specifically referenced in D2983 procedures. Attachment and positioning of the spindle during initial set up of the TESC System rather than immediately prior to the viscosity measurement also helps to lessen the impact of sample disruption on test results and enhance measurement precision. The sample remains undisturbed until testing is initiated.

Along with improvements in test precision and accuracy, the TESC System offers a number of advantages over alternative ASTM D2983 sample conditioning options. Automation of the entire conditioning and testing process reduces operator hands-on time and minimizes the opportunity for operator error in the testing procedure. Pre-programmed run profiles for typical gear oil and ATF viscosity ranges reduce set up time and ensure consistency in sample conditioning.

[5] For data, see Table 6 — ASTM Committee D02 Precision Evaluation.

Table 4: ATF Statistics

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	R Pct Diff
ATF1003	04/22/14	DV2T	2	-40	15142	1.9	14850	29.7	12	-40	1.95	4	-0.67
ATF1003	04/28/14	DV2T	2	-40	15142	1.3	14950	29.9	12	-40	1.28		
ATF1003	04/22/14	DV2T	2	-40	14846	0.6	14750	73.8	30	-40	0.65		-0.27
ATF1003	04/28/14	DV2T	2	-40	14846	0.4	14790	74	30	-40	0.38		
ATF1003	04/22/14	DV3T	1	-40	15142	2.9	14710	11	12	-40	2.89		0.48
ATF1003	04/28/14	DV3T	1	-40	15142	3.3	14640	11	12	-40	3.37		
ATF1003	04/22/14	DV3T	1	-40	14846	1.1	14680	27.5	30	-40	1.12		1.10
ATF1003	04/28/14	DV3T	1	-40	14846	2.2	14520	27.2	30	-40	2.22		
ATF1007	04/29/14	DV2T	2	-40	10365	0.6	10300	20.6	12	-40	0.63	3	
ATF1007	04/29/14	DV2T	2	-40	9497	-6.3	10100	50.5	30	-40	-6.15		
ATF1007	04/14/14	DV3T	1	-40	10080	3.4	9733	7.3	12	-39.9	3.50		0.00
ATF1007	04/29/14	DV3T	1	-40	10080	3.4	9733	7.3	12	-40	3.50		
ATF1007	04/14/14	DV3T	1	-40	10365	5.8	9760	18.3	30	-39.9	6.01		1.84
ATF1007	04/29/14	DV3T	1	-40	10365	7.6	9582	18	30	-40	7.85		
ATF1011	04/21/14	DV2T	2	-40	17038	2.9	16550	33.1	12	-40	2.91	4	-1.68
ATF1011	04/23/14	DV2T	2	-40	17038	1.2	16830	33.7	12	-40	1.23		
ATF1011	04/21/14	DV2T	2	-40	16147	0.4	16090	80.5	30	-40	0.35		-1.30
ATF1011	04/23/14	DV2T	2	-40	16147	-0.9	16300	81.5	30	-40	-0.94		
ATF1011	04/21/14	DV3T	1	-40	17038	2.8	16560	12.4	12	-39.9	2.85		0.42
ATF1011	04/23/14	DV3T	1	-40	17038	3.2	16490	12.4	12	-40	3.27		
ATF1011	04/21/14	DV3T	1	-40	16147	0.2	16110	30.2	30	-39.9	0.23		0.44
ATF1011	04/23/14	DV3T	1	-40	16147	0.7	16040	30.1	30	-40	0.66		
ATF1103	05/08/14	DV2T	2	-40	16402	5.5	15500	31	12	-40	5.65	3	
ATF1103	05/08/14	DV2T	2	-40	15737	2.3	15380	76.9	30	-40	2.29		
ATF1103	04/12/14	DV3T	1	-40	16402	11.4	14530	10.9	12	-39.9	12.10		-2.45
ATF1103	05/08/14	DV3T	1	-40	16402	9.2	14890	11.2	12	-40	9.66		
ATF1103	04/12/14	DV3T	1	-40	15737	6.9	14650	27.5	30	-39.9	7.15		-1.29
ATF1103	05/08/14	DV3T	1	-40	15737	5.7	14840	27.8	30	-40	5.87		
ATF1107	04/25/14	DV2T	2	-40	18650	-1.4	18920	37.8	12	-40	-1.44	3	

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	R Pct Diff
ATF1107	04/25/14	DV2T	2	-40	17947	-3.2	18520	92.6	30	-40	-3.14		
ATF1107	04/11/14	DV3T	1	-40	18650	2.8	18130	13.6	12	-39.9	2.83		-1.48
ATF1107	04/25/14	DV3T	1	-40	18650	1.3	18400	13.8	12	-40	1.35		
ATF1107	04/11/14	DV3T	1	-40	17947	0.7	17820	33.4	30	-39.9	0.71		-0.56
ATF1107	04/25/14	DV3T	1	-40	17947	0.2	17920	33.6	30	-40	0.15		
ATF1111	04/27/14	DV2T	2	-40	18713	0.7	18580	37.2	12	-40	0.71	3	
ATF1111	04/27/14	DV2T	2	-40	18304	1.0	18130	90.6	30	-40	0.96		
ATF1111	04/19/14	DV3T	1	-40	18713	4.5	17870	13.4	12	-40	4.61		-5.28
ATF1111	04/27/14	DV3T	1	-40	18713	-0.7	18840	14.1	12	-40	-0.68		
ATF1111	04/19/14	DV3T	1	-40	18304	4.1	17560	32.9	30	-40	4.15		-4.45
ATF1111	04/27/14	DV3T	1	-40	18304	-0.3	18360	34.4	30	-40	-0.31		
ATF1203	04/20/14	DV2T	2	-40	12096	6.3	11340	22.7	12	-40	6.45	4	0.35
ATF1203	05/01/14	DV2T	2	-40	12096	6.6	11300	22.6	12	-40	6.80		
ATF1203	04/20/14	DV2T	2	-40	11117	-1.8	11320	56.6	30	-40	-1.81		1.24
ATF1203	05/01/14	DV2T	2	-40	11117	-0.6	11180	55.9	30	-40	-0.57		
ATF1203	04/20/14	DV3T	1	-40	12096	9.6	10930	8.2	12	-39.9	10.13		-2.80
ATF1203	05/01/14	DV3T	1	-40	12096	7.1	11240	8.4	12	-40	7.34		
ATF1203	04/20/14	DV3T	1	-40	11117	2.0	10900	20.4	30	-39.9	1.97		-2.27
ATF1203	05/01/14	DV3T	1	-40	11117	-0.3	11150	20.9	30	-40	-0.30		
ATF1207	05/03/14	DV2T	2	-40	11307	1.7	11120	22.2	12	-40	1.67	3	
ATF1207	05/03/14	DV2T	2	-40	11292	2.1	11060	55.3	30	-40	2.08		
ATF1207	04/17/14	DV3T	1	-40	11307	2.1	11070	8.3	12	-39.9	2.12		1.00
ATF1207	05/03/14	DV3T	1	-40	11307	3.1	10960	8.2	12	-40	3.12		
ATF1207	04/17/14	DV3T	1	-40	11292	1.2	11160	20.9	30	-39.9	1.18		2.17
ATF1207	05/03/14	DV3T	1	-40	11292	3.3	10920	20.5	30	-40	3.35		
ATF1211	04/24/14	DV2T	2	-40	18646	3.2	18050	36.1	12	-40	3.25	3	
ATF1211	04/24/14	DV2T	2	-40	17928	0.4	17860	89.3	30	-40	0.38		
ATF1211	04/18/14	DV3T	1	-40	18646	9.2	16930	12.7	12	-39.9	9.65		-3.14
ATF1211	04/24/14	DV3T	1	-40	18646	6.3	17470	13.1	12	-40	6.51		

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	R Pct Diff
ATF1211	04/18/14	DV3T	1	-40	17928	5.3	16970	31.8	30	-40	5.49		-2.44
ATF1211	04/24/14	DV3T	1	-40	17928	3.0	17390	32.6	30	-40	3.05		
ATF1303	05/02/14	DV2T	2	-40	15914	4.3	15230	30.5	12	-40	4.39	3	
ATF1303	05/02/14	DV2T	2	-40	16604	8.9	15120	75.6	30	-40	9.36		
ATF1303	04/14/14	DV3T	1	-40	15914	8.5	14560	10.9	12	-39.9	8.89		-1.63
ATF1303	05/02/14	DV3T	1	-40	15914	7.0	14800	11.1	12	-40	7.25		
ATF1303	04/14/14	DV3T	1	-40	16604	11.9	14630	27.4	30	-39.9	12.64		-0.75
ATF1303	05/02/14	DV3T	1	-40	16604	11.2	14740	27.6	30	-40	11.89		
ATF1307	04/26/14	DV2T	2	-40	17923	0.1	17900	35.8	12	-40	0.13	3	
ATF1307	04/26/14	DV2T	2	-40	17798	0.4	17720	88.6	30	-40	0.44		
ATF1307	04/10/14	DV3T	1	-40	17923	2.5	17470	13.1	12	-40	2.56		-0.74
ATF1307	04/26/14	DV3T	1	-40	17923	1.8	17600	13.2	12	-40	1.82		
ATF1307	04/10/14	DV3T	1	-40	17798	1.2	17590	33	30	-39.9	1.18		0.86
ATF1307	04/26/14	DV3T	1	-40	17798	2.0	17440	32.7	30	-40	2.03		
ATF1311	05/04/14	DV2T	2	-40	17366	0.8	17230	34.4	12	-40	0.79	3	
ATF1311	05/04/14	DV2T	2	-40	16497	-1.7	16780	83.9	30	-40	-1.70		
ATF1311	04/05/14	DV3T	1	-40	17366	3.3	16800	12.6	12	-39.9	3.31		-0.77
ATF1311	05/04/14	DV3T	1	-40	17366	2.5	16930	12.7	12	-40	2.54		
ATF1311	04/05/14	DV3T	1	-40	16497	-0.6	16600	31.1	30	-39.9	-0.62		0.00
ATF1311	05/04/14	DV3T	1	-40	16497	-0.6	16600	31.1	30	-40	-0.62		
ATF1403	04/30/14	DV2T	2	-40	13946	-2.2	14250	28.5	12	-40	-2.16	3	
ATF1403	04/30/14	DV2T	2	-40	14337	1.0	14200	71	30	-40	0.96		
ATF1403	04/16/14	DV3T	1	-40	13946	0.5	13870	10.4	12	-40	0.55		-0.93
ATF1403	04/30/14	DV3T	1	-40	13946	-0.4	14000	10.5	12	-39.9	-0.39		
ATF1403	04/16/14	DV3T	1	-40	14337	2.8	13940	26.1	30	-40	2.81		-0.64
ATF1403	04/30/14	DV3T	1	-40	14337	2.1	14030	26.3	30	-40	2.16		
Avg Dif											2.79		-0.80
Min											-6.15		-5.28

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	R Pct Diff
Max											12.64		2.17
Sdev											3.55		1.68
Number											84	13	32
Total tests												42	

Table 5: Gear Oil Statistics

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	r Pct Diff
GO1008	05/30/14	DV2T	2	-26	111716	1.8	109700	27.4	1.5	-26	1.82	2	
GO1008	05/30/14	DV2T	2	-26	111716	2.5	108900	54.5	3	-26	2.55		
GO1008	05/30/14	DV3T	1	-26	111716	4.7	106500	39.9	6	-26	4.78		
GO1008	05/30/14	DV3T	1	-26	111716	5.1	106000	79.5	12	-26	5.25		
GO1012	06/01/14	DV2T	2	-26	112630	-4.0	117100	29.3	1.5	-26	-3.89	2	
GO1012	06/01/14	DV2T	2	-26	112630	-2.5	115500	57.8	3	-26	-2.52		
GO1012	06/01/14	DV3T	1	-26	112630	1.3	111200	41.7	6	-26	1.28		
GO1012	06/01/14	DV3T	1	-26	112630	3.0	109200	81.9	12	-26	3.09		
GO1104	06/05/14	DV2T	2	-26	11771	6.1	11050	22.1	12	-26	6.32	2	
GO1104	06/05/14	DV2T	2	-26	11771	6.5	11010	55	30	-26	6.68		
GO1104	06/05/14	DV3T	1	-26	11771	7.1	10930	8.2	12	-26	7.41		
GO1104	06/05/14	DV3T	1	-26	11771	7.6	10880	20.4	30	-26	7.87		
GO1108	06/06/14	DV2T	2	-26	11522	4.3	11030	22.1	12	-25.9	4.36	2	
GO1108	06/06/14	DV2T	2	-26	11522	4.3	11030	55.2	30	-26	4.36		
GO1108	06/06/14	DV3T	1	-26	11522	6.3	10800	8.1	12	-26	6.47		
GO1108	06/06/14	DV3T	1	-26	11522	5.7	10870	20.4	30	-26	5.82		
GO1204	06/04/14	DV2T	2	-26	119284	2.3	116600	29.1	1.5	-25.9	2.28	2	
GO1204	06/04/14	DV2T	2	-26	119284	1.7	117200	58.6	3	-26	1.76		
GO1204	06/04/14	DV3T	1	-26	119284	4.3	114100	42.8	6	-26	4.44		
GO1204	**06/04/14**	DV3T	1	-26	119284	4.4	114000	85.5	12	-26	4.53		

Sample	Test Date	Viscometer	TESC	Watlow Temperature	ILCP Viscosity	ILCP delta Pct	Viscosity	Torque	Speed	DVT Temperature	R Pct Diff	Number of TESC Tests	r Pct Diff
GO1208	**06/09/14**	DV2T	2	-26	60823	-18.0	71770	35.9	3	-25.9	-16.51	2	
GO1208	**06/09/14**	DV2T	2	-26	60823	-10.1	66970	67	6	-25.9	-9.62		
GO1208	**06/09/14**	DV3T	1	-26	60823	-8.0	65690	24.6	6	-26	-7.69		
GO1208	**06/09/14**	DV3T	1	-26	60823	-2.9	62600	47	12	-26	-2.88		
GO1212	**05/31/14**	DV2T	2	-26	59841	-15.8	69270	34.6	3	-26	-14.61	4	0.87
GO1212	**06/11/14**	DV2T	2	-26	59841	-14.8	68670	34.3	3	-25.9	-13.74		
GO1212	**05/31/14**	DV2T	2	-26	59841	-9.6	65600	65.6	6	-26	-9.18		0.72
GO1212	**06/11/14**	DV2T	2	-26	59841	-8.8	65130	65.1	6	-25.9	-8.46		
GO1212	**05/31/14**	DV3T	1	-26	59841	-7.3	64220	24.1	6	-26	-7.06		1.60
GO1212	**06/11/14**	DV3T	1	-26	59841	-5.6	63200	23.7	6	-26	-5.46		
GO1212	**05/31/14**	DV3T	1	-26	59841	-2.9	61600	46.2	12	-26	-2.90		1.31
GO1212	**06/11/14**	DV3T	1	-26	59841	-1.6	60800	45.6	12	-26	-1.59		
GO1312	06/08/14	DV2T	2	-26	5222	-3.4	5400	10.8	12	-25.9	-3.35	2	
GO1312	06/08/14	DV2T	2	-26	5222	-2.3	5340	26.7	30	-25.9	-2.23		
GO1312	06/08/14	DV3T	1	-26	5222	1.3	5156	3.9	12	-26	1.27		
GO1312	06/08/14	DV3T	1	-26	5222	-1.1	5280	9.9	30	-26	-1.10		
GO1404	06/03/14	DV2T	2	-26	86945	0.8	86270	43.1	3	-26	0.78	2	
GO1404	06/03/14	DV2T	2	-26	86993	2.0	85230	85.2	6	-26	2.05		
GO1404	06/03/14	DV3T	1	-26	86993	1.4	85780	32.2	6	-26	1.40		
GO1404	06/03/14	DV3T	1	-26	86993	1.5	85670	64.3	12	-26	1.53		
Avg Diff											-0.62		1.12
Min											-16.51		0.72
Max											7.87		1.60
Sdev											6.31		0.40
Number											40	9	4
Total tests												20	

Table 6: ASTM Committee D02 Precision Evaluation

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ASTM Committee D02 Precision Evaluation           17:34, 1 Aug 2014

                                TESC D2983

              Repeatability   = .275E-01 *  (X + .0000) mPa(s)
              Reproducibility = .860E-01 *  (X + .0000) mPa(s)

                                       Initial    Final
                Number of laboratories     2        2
                Number of samples          8        8
                Number of repeats          2

REGRESSIONS (AFTER OUTLIER TESTS)          TRANSFORMATION TYPE: NONE

                                       Coefficient          t-      %
Regression              Fitted Variable      B       Test  Ratio  Sig.

Unweighted d v. (m+B0)  m + 3.9073E+04   2.8204E-03  B=0   2.21   7.0
Unweighted D v. (m+B0)  m - 5.2314E+03   1.8841E-02  B=0  21.67   0.0

Weighted                Intercept       -7.81397E+00
  ln(d,D) v. ln(m+B0)   ln(m         )   1.27092E+00 B=1   1.37  19.5
(for Log Transform)     Indicator       -2.64465E+00
                        Indicator * Ln(m+B0) 2.68416E-01 B=0 2.32   3.9

Weighted                Intercept       -4.17007E+00
  ln(d,D) v. ln(m+B0)   ln(m         )   9.59438E-01 B=0   6.02   0.0
(for Power Transform)   Indicator       -1.81345E+00
                        Indicator * Ln(m+B0) 1.96319E-01 B=0 2.10   5.8

                               Critical t (5%, 12) =     2.18   5.0

                     Transformation: ln(.0000 + X)
```

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COMMENTS:

This report was prepared using D2PP, Version 3.1.96
from data file TESCPrelim2.DAT, 8/1/2014 5:26:23 PM

DATA MISSING OR REJECTED (Data rejection limit 20%):

LABORATORY SAMPLE DUP TEST

CAUTION!!
<30 good cells
<5 laboratories
<30 Lab x Sample DF

SAMPLE MEANS AND STANDARD DEVIATIONS Transform Type: NONE
After any outlier rejections.

Sample	No. of Results	Mean	Between Labs S.D.	DF	R	Between Repeats S.D.	DF	r
ATF1203(30	4	11138.	188.6	2	.11E+04	143.3	2	.87E+03
ATF1203(12	4	11203.	199.6	2	.12E+04	156.3	2	.95E+03
ATF1003(30	4	14685.	133.6	1	.24E+04	82.46	2	.50E+03
ATF1003(12	4	14753.	140.8	2	.86E+03	125.0	2	.76E+03
ATF1011(30	4	16135.	115.4	3	.52E+03	110.7	2	.67E+03
ATF1011(12	4	16608.	155.0	2	.94E+03	144.3	2	.88E+03
GO1212(6)	4	64538.	1236.	1	.22E+05	561.5	2	.34E+04
GO1204	4	.11548E+06	2027.	1	.36E+05	304.1	2	.19E+04

SAMPLE MEANS AND STANDARD DEVIATIONS Transform Type: Ln
After any outlier rejections.

Sample	No. of Results	Mean	Between Labs S.D.	DF	R	Between Repeats S.D.	DF	r
ATF1203(30	4	9.3180	.1699E-01	2	.10	.1293E-01	2	.79E-01
ATF1203(12	4	9.3238	.1793E-01	2	.11	.1409E-01	2	.86E-01
ATF1003(30	4	9.5946	.9116E-02	1	.16	.5644E-02	2	.34E-01
ATF1003(12	4	9.5991	.9511E-02	2	.58E-01	.8436E-02	2	.51E-01
ATF1011(30	4	9.6887	.7134E-02	3	.32E-01	.6839E-02	2	.42E-01
ATF1011(12	4	9.7176	.9298E-02	2	.57E-01	.8651E-02	2	.53E-01
GO1212(6)	4	11.075	.1918E-01	1	.34	.8775E-02	2	.53E-01
GO1204	4	11.657	.1755E-01	1	.32	.2604E-02	2	.16E-01

VARIANCE ANALYSIS Transform Type: Ln

	Sum of squares Estimated	Sum of squares Exact	DF	Mean square	F
Sample Means	2.129690E+01	2.129690E+01			

Lab Means	2.147079E-03	2.147079E-03	1	2.14708E-03	40.374
Interaction	3.722568E-04		7	5.31795E-05	
Pairs	2.129942E+01	2.129942E+01			
Repeats	1.348754E-03		16	8.42971E-05	
Total	2.130077E+01				
Critical F (5%, 1, 7) =					5.591

	Mean Square	Expected Mean Square (Pref = New)
Lab means	2.14708E-03	V(r) + 1.0000 V(I) + 16.0000 V(L)
Interaction	5.31795E-05	V(r) + 1.0000 V(I)
Repeats	8.42971E-05	V(r)

	DF	Variance	Precision
Transformed data			
Repeatability	16	1.685942E-04	2.753E-02
Reproducibility	2	3.992141E-04	8.597E-02

INPUT DATA FOR:

TESC D2983

GO1212(6)	ATF1003(12	ATF1003(30	ATF1011(12	ATF1011(30
ATF1203(12	ATF1203(30	GO1204		
Lab A				
65600.	14710.	14750.	16550.	16090.
11340.	11320.	.11660E+06		
65130.	14950.	14790.	16830.	16300.
11300.	11180.	.11720E+06		
Lab B				
64220.	14710.	14680.	16560.	16110.
10930.	10900.	.11410E+06		
63200.	14640.	14520.	16490.	16040.
11240.	11150.	.11400E+06		

Table 6: ASTM D02 Committee D02 Precision Evaluation